# AMSD Alignment Lessons Learned

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# Outline

- Overview of Test Procedure
- Selected Details
- Repeatability and Reproducibility Tests
- Summary

# Overview of Test Procedure

- Phase I: Ambient Pressure
  - Align Instantaneous Phase Interferometer (IPI) to Null
    - ♦ Record position of null in pixel space
  - Rough Alignment of surface to IPI/Null
    - ♦ Using spot projectors
    - ♦ Gets surface within 0.5-1.0mm of alignment
    - ♦ Requires fiducials to be where they are expected
- Phase II: Vacuum
  - Align surface to expected figure
    - ♦ Using Zernike aberrations, optimization
    - ♦ Including gravity and figure errors
    - ♦ Record all available mirror fiducial locations

# Overview of Test Procedure

- Record ADM Measurement for ROC
  - Distance to null face
  - Distance to AMSD
  - Distance to Window
- Baseline Measurement Complete!

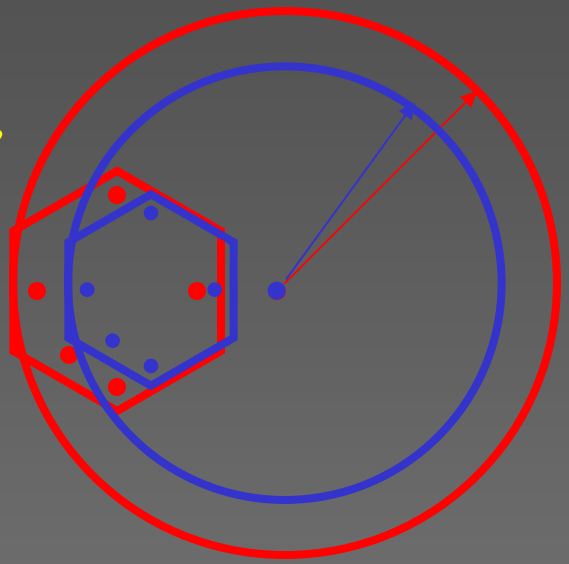
- Phase III
  - Use locations of mirror fiducials as targets for future alignments

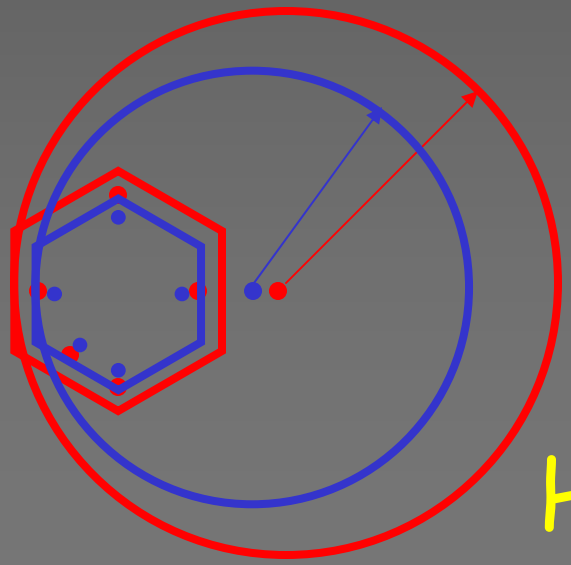
# Detail (for Be): 2 Nulls, 1 AMSD

- Be CTE results in a ~13mm change in ROC
  - Two nulls: 10013mm and 10000mm ROC
    - 200K Measurement made with both nulls
    - Designs require 6.5mm refocus and 0.136mm horizontal realignment of pallet when switching out null
    - Views with two designs are horizontally displaced from each other (FoV's shifted).
      - Affects fiducial targets in pixel space for final cryo measurement
  - Cryo shrinkage means fiducials have moved relative to vertex of best fit parabola.
    - Affects intermediate temperature measurements

# Detail (for Be): 2 Nulls, 1 AMSD

How fiducials move





How we are aligned at intermediate temperatures

# Detail (for Be): 2 Nulls, 1 AMSD

- The transformation in parent space of ambient fiducials targets to cryo fiducial targets is required:
  - This approach means that perfect fiducial alignment at all temperatures (ROC's) for a perfect mirror would show no misalignment induced aberrations only at the initial ambient temperature (10013mm) and at the final cryo temperature (10000mm).
- Future tests should optimize differences and realignments between two null designs.

# Detail: Acquiring Mirror Fiducials

- This process is quite repeatable,
  - Charts to follow…
- but it can be time consuming, depending on number of fiducials,
- and subject to variation due to:
  - pupil focus changes
  - mirror tilt changes
  - operator changes
- So, if this approach is used in future tests
  - Never change pupil focus (not changed during AMSD tests)
  - Align to nearly same fringe pattern for every alignment
  - Use same operator OR train operators to be consistent

# Detail: Mirror Fiducial Repeatability

- Acquired 3 sets of mirror fiducials for a single alignment
- Calculated mirror alignments with all 3 sets
- Alignments varied by:
  - 0.05mm Std.Dev. Horizontal
  - 0.05mm Std.Dev. Vertical
  - 9 seconds Std.Dev. Roll
    - ♦ Equivalent to 0.11mm Vertical

# Detail: Null Fiducial Repeatability

- Acquired 4 sets of null fiducials for a single alignment
- Calculated mirror alignments with all 4 sets
- Alignments varied by:
  - 0.15mm Std.Dev. Horizontal
  - 0.09mm Std.Dev Vertical
  - 42 seconds Std.Dev Roll
    - Equivalent to 0.27mm Vertical
    - Due to instability of this roll calculation, we only use translations

# Detail: Total Repeatability

- RSS of Horizontal Errors: 0.16mm
  - Corresponds to 19nm surface rms
- RSS of Vertical Errors (No Null Roll): 0.15mm
  - Corresponds to 18nm surface rms
- RSS H and V: 26nm Surface Uncertainty
- To allow the possibility of some real null roll
  - Widen RSS of Vertical Errors: 0.20mm
  - Corresponds to 22nm surface rms
- Full Surface Uncertainty: 29nm rms

# Detail:
# IPI Repeatability

- 5 maps, each with 25 averaged frames, were acquired in sequence
- Tilt was removed in Opticode
- "Averaging" option applied in Opticode
  - Generates a report on the statistics of the sets
- Surface rms's varied by 2nm rms

# Detail: Null Installation Repeatability

- Null was removed, then reinstalled, then a Map was acquired: 5 times
  - Null alignment was not monitored / adjusted
- Tilt was removed in Opticode
- "Averaging" option applied in Opticode
- Surface rms's varied by 5nm rms
- NOTE: This test occurred over a very short time, not days.

# Detail: System Reproducibility (1)

- A good alignment was acquired.
  - 5 Maps were taken
- Entire system was significantly misaligned.
  - Null was snapped out and in 5 times
  - Hexapod was yawed back and forth 5 times
  - Hexapod was translated in Horiz & Vert
  - Mirror stage (NMSS) used to reacquire return beam
- A new good alignment was acquired and maps obtained.
  - 5 Maps were taken

# Detail: System Reproducibility (2)

- Computed misalignments of each measurement
- Alignments matched to within:
  - 0.021mm vertical
  - 0.136mm horizontal
  - 16nm rms surface
- This is within calculated uncertainties

# Additional Items

- ADM measurements are extremely precise.
- Know your stages.
- Set a single coordinate system.
- Segment roll is critical to monitor and correct.
- Pupil image quality shows significant variations over the full pupil.

# Summary

- Specify multi-null designs carefully.
- Improve or Remove (bypass) null marking.
- If mirror fiducial approach is used
  - NEVER change the pupil focus
  - Align to nearly same fringe pattern for every alignment
  - Use same operator or consistent operators